Factors Influencing Occurrence, Scale, Mobility, Runout, and Morphology of Mass Movements on the Continental Slope

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LONG-TERM GOALS

Our long term goals are to understand how geotechnical and physical properties develop in marine sedimentary deposits on continental margins as a result of various biological, geochemical and mechanical processes. From these considerations we also want to understand how these properties can influence sediment transport processes and the development of the final geomorphology. Our studies include predicting the stability of slopes within the continental terrace and distinguishing morphologic features caused by slope failure from those caused by other gravity-driven processes, including turbidity-current flow. A major component of the development of mobility is to understand the transition between initial slope failure and the development of debris flows and turbidity currents and predicting the rheological properties that determine the dynamics of such flows.

OBJECTIVES

Our main objectives for FY03 focused on the following: (1) complete our final contributions related to STRATAFORM related to coring and final data analysis; (2) initiate our involvement in project PASTA and EuroSTRATAFORM by focusing our study on (i) microstructural signature of deformed Adriatic sediments and (ii) characterize strength evolution in shallow sediments of the Po Delta; (3) quantify the effect of bioturbation on of strength development on cores from the Adriatic Sea; (4) evaluate the mobility of Adriatic sediments. The work on Adriatic cores should also give the opportunity to initiate our work on (5) predicting the regional variation of erodability, stability, and penetrability of the nearshore seabed and sediment mobility by (6) developing index properties relationships that can be determined easily or, potentially, mapped remotely in order to relate regionally distributed geotechnical properties. Another objective of FY03 is to (7) assess the signatures of catastrophic events to determine whether they are produced by deformational (landsliding) or depositional (turbidity current sediment waves) processes. A final objective is also to (8) provide modelers with easily determined relationships which can be used to predict sediment strength and rheological properties of sediments.

APPROACH

Our research focuses on the factors that lead to variations in the sedimentological and environmental conditions determining sediment characteristics and their influence on failure and post failure behavior. We develop improved correlation between engineering classifications and strength factors.

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We relate compressibility, physico-chemical properties and strength to sediment microstructure, observed using SEM techniques and CATSCAN profiling. We simulate sediment accumulation in specially designed large cells. We measure sediment rheological properties in a viscometer. Geotechnical properties are related to sediment density state, obtained from detailed logs of downcore variability of sediment density and sound velocity. Basic strength parameters are obtained using triaxial drained and undrained tests and undrained cyclic tests. Using available bathymetry, and seismic profiles, we develop models tested for stability and mobility. If there is charging by bubble-phase gas, or if earthquake shaking disrupts the sediment fabric and causes it to collapse with a resulting increase in the pressure of interstitial fluids. Driving stresses are balanced against strength variations in a geographic Information System (GIS) to obtain a regional estimate of relative slope stability.

Key individuals, at Laval: Jacques Locat, Jean-Marie Konrad, Serge Leroueil, and Marie-Claude Lévesque and Pierre Therrien: strength and compressibility measurements, SEM studies, rheology measurements, and simulation of sediment accumulation.; at the USGS: Homa Lee, Dianne Minasian, and Pete Dartnell: physical property logs of sediment cores and relations between geotechnical and classification properties, algorithms relating sediment properties, environmental factors, and slope stability within the framework of a GIS.

WORK COMPLETED

During FY 03, we completed the work related to STRATAFORM project on the New Jersey margin and made significant advances in completing related publications. We contributed to the effort in evaluating the potential use of the GLAD800 for coring on the shelf and slope and to provide geotechnical quality samples. We initiated the analysis of cores from Ortona (Italy) to study the microstructural signatures of a flow layer. This involved carrying geotechnical testing on cores (strength, liquidity index,water content), SEM and mineralogical investigations in addition to physico-chemical properties such as specific surface area, cation exchange capacity and some chemical analyses. We completed the sampling and preliminary analyses of cores from the Po Delta by the use of a detailed CATSCAN profiling for all cores. We also completed during the fall of 2002 the SEM and mineralogical analyses of San Francisco Bay mud samples used to test some hypothesis concerning seismic strengthening tests carried out at the USGS in a series of cyclic simple shear tests. This had been done in preparation for further tests on the Adriatic sediments to be obtained in FY03.

RESULTS

Our analysis of the GLAD800 indicated that this drilling platform is not ready yet (as of November 2002) for operating efficiently on the shelf under typical wave conditions (Lévesque 2002). Our final slope stability analysis of the Hudson Apron along the New Jersey Margin has indicated that if the ODP geotechnical investigation is correct, the actual factor of safety of the slope is marginal and that the required pore pressures to trigger a failure had to be significantly high (Figure 1). For the Hudson Apron site, it is also of interest to note that using considering the slope material is a Bingham material the actual yield strength required to maintain the slope stable is close to the measured undrained shear strength at a depth of about 150 to 200mbelow the sea floor (Locat et al.2003a). Our preliminary analysis of the microstructure of Ortona samples in the Adriatic Sea could be used to identify a flow layer, as presented at the EuroSTRATAFORM session at the AGU meeting in Nice (Lévesque et al. 2003). From the cores taken downstream from the mouth of the Po Delta we could observed a very intense bioturbation of most layer. As we are in theprocess of defining ways to quantify the bio-

porosity index of a sediment we could clearly illustrate the extent of the bioturbation by looking at various down the core sections (Figure 2).

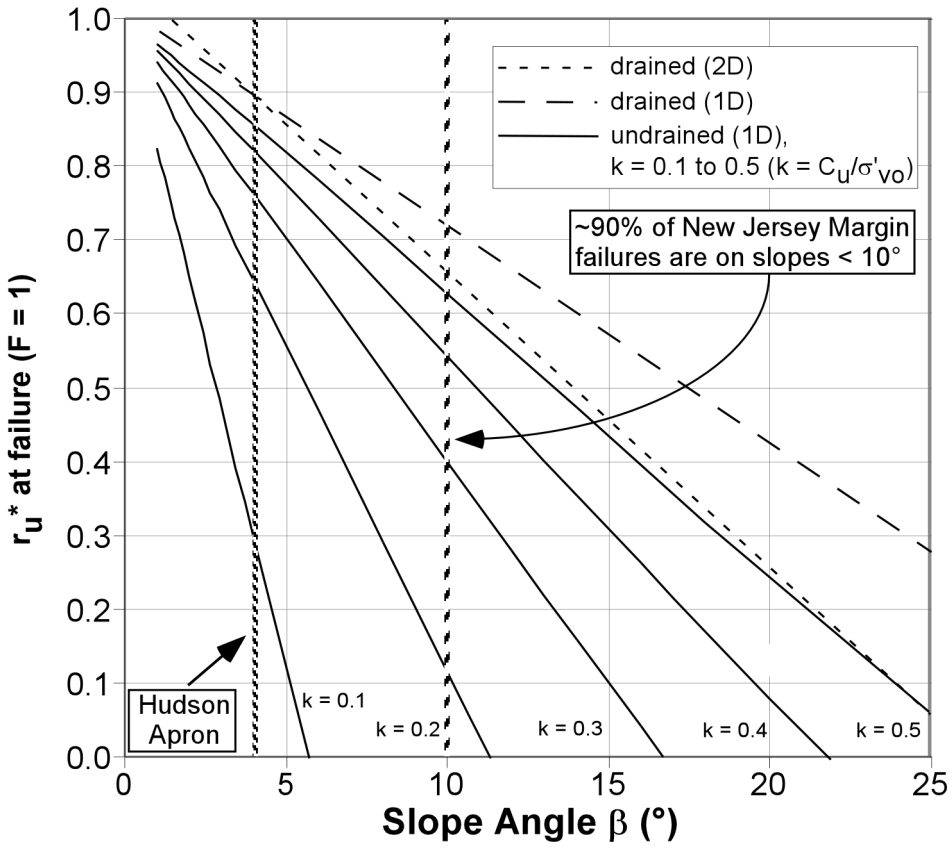

Figure 1. Parametric analysis linking the slope angle and the pore pressure required for a factor of safety of one along the New Jersey Margin (from Locat et al. 2003).

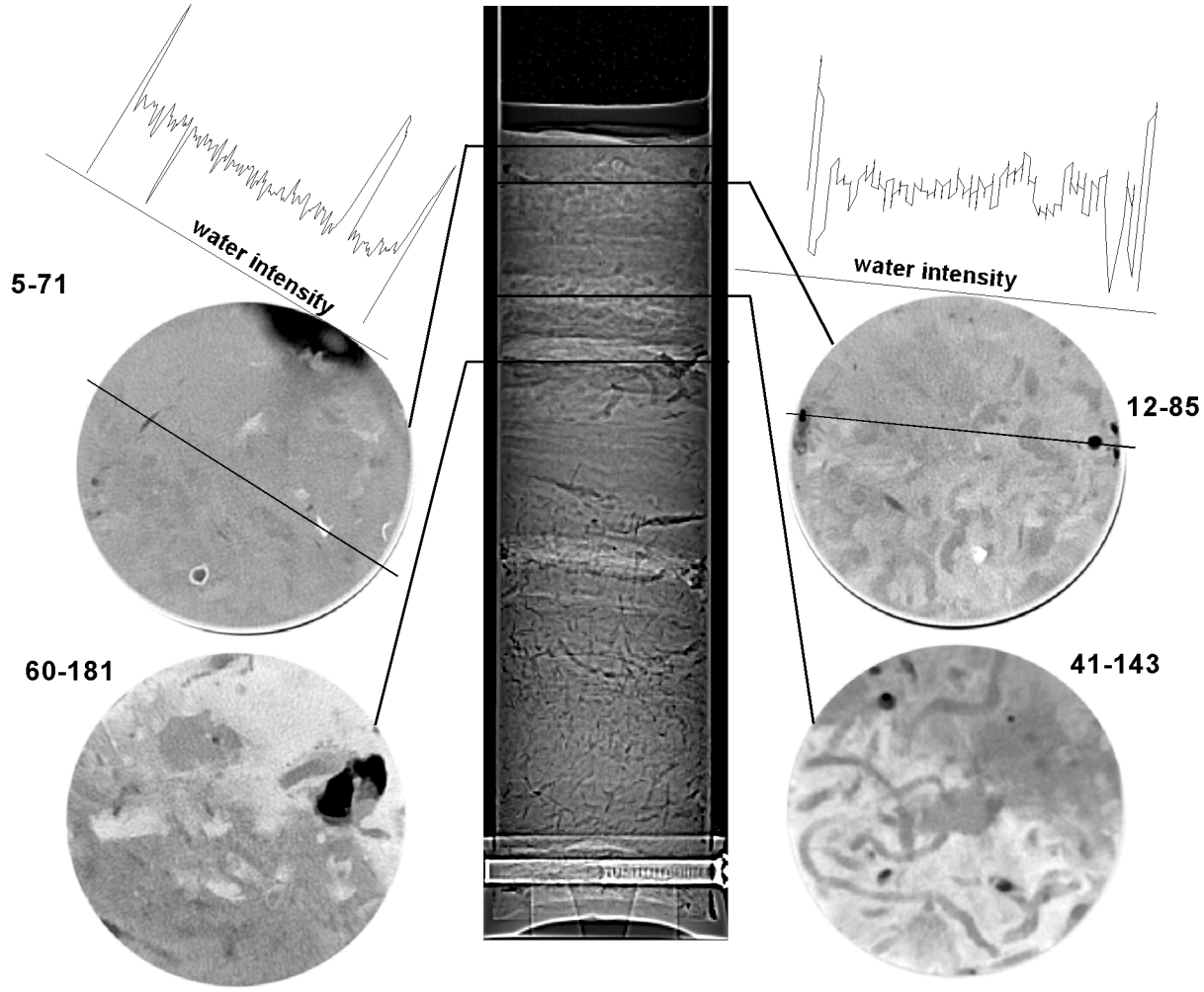

Figure 2. Example of a CatScan analysis (vertical and plan views) of core E11 taken near the mouth of the Po River delta at a depth of 11 m. The total height of the core is 35 cm. Also shown are the tomographic density profiles along two horizontal sections.

IMPACT/APPLICATION

Relationships developed in this project show the importance of sediment liquidity index and seabed density profiles in representing the behavior of marine sediment. These values can be used to predict regional slope stability and the rheological behavior of debris flows. General strength-density relationships can be used for modeling sediment accumulation and stability. We are also currently working on the definition of a bio-porosity index to include in the measurement of the shear strerngth of near surface sediments.

TRANSITIONS

Geoacoustic properties are being used by mappers and acousticians to identify lithologies acoustically (Locat and Sanfacon, 2002). Rheological properties are being used by modelers to represent debris flows (Imran et al. 2001). Landslide generation models are being used by landscape evolution modelers. Offshore research groups interested in margin and in oil and energy development were used

as a platform to present our knowledge on submarine slope stability and hazard acquired as part of STRATAFORM. We have also contributed to a major effort in assembling all the existing knowledge on submarine mass movements and their consequences by publishing a book containing refereed papers on the topic (Locat and Mienert 2003) including papers by Lee et al. (2003) and Locat et al.2003a) related to STRATAFORM. We also transferred our knowledge developed as part of STRATAFORM to those interested in tsunami modeling (Locat et al.2003b).

RELATED PROJECTS

Lee has developed a USGS project to investigate sediment and pollutant transport on the Los Angeles margin that uses techniques produced by STRATAFORM. The development of this project benefited from approaches developed within STRATAFORM. Recently, a group of Canadians led by J. Locat, and H. Lee developed a new project with project COSTA (COntinental Slope STAbility) in Europe that will last until 2005.

REFERENCES

Imran, J., Parker, G., Locat, J., and Lee, H., 2001. A 1-D numerical model on muddy subaqueous and subareial debris flows. Submitted to ASCE Journal of Hydraulic Engineering. 127: 959-968.

Lévesque, M.-C., 2002. Rapport de mission sur le KNORR sur la côte est du New Jersey, projet STRATAFORM. Gregi Report no ULKNORR02-10, October 2002, 4 pages.

Lévesque, M.-C., Locat, J., Trincardi, F., and Lee, H., 2003. Nature and microstructure of some late-Holocene Adriatic shelf sediments. EGU-AGU meeting in Nice, France. Abstract. [published]

Locat, J., 1997. Normalized rheological behavior of fine muds and their flow properties in a pseudoplastic regime. *In: Debris flow hazards mitigation, mechanics, prediction and assessment*. Water Resources Engineering Division, ASCE, pp. 260-269.

Locat, J., and Mienert, J., 2003. Submarine Mass Movements and Their Consequences. Kluwer Series on Advances in Natural and Technological Hazards No. 19, 540p. [published, refereed]

Locat, J., and Sansfaçon, R., 2002. Multibeam survey: a major tool for geosciences. Sea Technology, 43: 39-47.

Locat, J., Desgagnés, P., Leroueil, S., and Lee, H.J., 2003a. Stability of the Hudson Apron slope off New Jersey. In: Submarine mass Movements and Their Consequences, J. Locat and J. Mienert, Eds., Kluwer series on Natural and Technological Hazards, vol. 19, pp.: 257-270. [published, refereed]

Locat, J., Lee. H.J., and Locat, P., 2003b. Numerical analysis of the mobility of the Palos Verdes debris avalanche. Accepted for publication in Marine Geology. [in press, refereed]

Locat, J., Lee, H., and Locat, P., 2002. Analysis of Submarine Mass Movements and its Implication for the Generation of Tsunamis, with a Particular Reference to the Palos Verdes Slide, California. Submitted to Marine Geology.

Locat, J., and Lee, H.J., 2002. Submarine landslides: advances and challenges. Keynote presentation, 8th International Symposium on Landslides, Cardiff, U.K., June 2000. Canadian Geotechnical Journal, 39: 193-212.

PUBLICATIONS

Lee, H.J., Kayen, R.E., Gardner, J.V., and Locat, J., 2003. Characteristics of several tsunamogenic submarine landslides. In: Submarine mass Movements and Their Consequences, J. Locat and J. Mienert, Eds., Kluwer series on Natural and Technological Hazards, vol. 19, pp.: 345-354. [published, refereed]

Lee, H.J. and Locat, J., Mobilization of submarine flows: examples and questions, Proceedings, International Workshop on "Occurrence and mechanisms of flows in natural slopes and earthfills, 15 pp.[in press]

Lee, H.J., Syvitski, J.P.M., Parker, G., Orange, D., Locat, J., Hutton, E.W.H., and Imran, J., 2002 Distinguishing sediment waves from slope failure deposits:field examples, including the 'Humboldt Slide', and modelling results, Marine Geology [in press, refereed]

Lévesque, M.-C., and Locat, J., 2003. Report analysis on San Francisco Bay Clay (Sample SBWR-43). Gregi Report no ULSFBS02-12, décembre 2002, 39p.

Lévesque, M.-C., 2003. Cruise report on the Seward Johnson II Cruise 2003-06 on the Adriatic sea, Po River Delta., Gregi Report no ULSJII03-06, 45p.

Leroueil, S., Locat, J., Lévesque, C., and Lee, H.J., 2003. Towards an approach for the assessment of the associated risk with submarine mass movements. In: Submarine mass Movements and Their Consequences, J. Locat and J. Mienert, Eds., Kluwer series on Natural and Technological Hazards, vol. 19, pp.: 59-68. [published, refereed]